Reinventing Submarine Signature Measurements: Installation of the High Gain Measurement System at SEAFAC

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Abstract – **Southeast Alaska Acoustic Measurement Facility (SEAFAC), the Navy's premier site for measurement and assessment of submarine signatures located just outside Ketchikan, Alaska, is comprised of three primary sites: the Shore Facility, the Static Site, and the Underway Site. In June 2008, the Underway Site was upgraded by Naval Surface Warfare Center, Carderock Division, Puget Sound Detachment (NSWCCD) and Science Applications International Corporation (SAIC) with new acoustic measurement arrays to support the upgraded requirements of the submarine fleet. The new, twin acoustic measurement arrays are each 1,120 feet long with single-point moorings and custom, dynamic "lazy-S" umbilical connecting the arrays to a commercial-off-the-shelf (COTS) submarine telecommunications cable to shore. These components were successfully installed, using an intricately prepared and executed plan, using assets mostly local to the Ketchikan, Alaska, area.**

I. Introduction

Submarine superiority depends on acoustic stealth. The U.S. Navy assesses and maintains the acoustic signatures of submarines through advanced measurement technology to quantify and diagnose noise sources. The data collected during full-scale measurements allows scientists to calculate the submarine's vulnerability to threat sensors, as well as to improve operations, tactics, and ship design.

Understanding submarine acoustic signatures demands robust, accurate, and reliable measurements. The key performance parameter of an acoustic measurement system is the ability to discriminate between ambient noise and the ship's signature. As submarines get quieter, measurement technology must improve.

Established in 1991, the Southeast Alaska Acoustic Measurement Facility (SEAFAC), located in Behm Canal, near Ketchikan, Alaska, is the Navy's premier site for the measurement and assessment of submarine signatures in static and dynamic geometries. The original Radiated Energy Signal Acquisition Systems (RESAS) arrays were installed in 1995, and periodic technical updates were conducted on these arrays, but after thirteen years of service, they were at the end of their useful life.

The Naval Surface Warfare Center, Carderock Division, Puget Sound Detachment (NSWCCD) with Science Applications International Corporation (SAIC), Ocean Technology Division, designed the High Gain Measurement System (HGMS) to meet the measurement requirements for advanced submarine classes. In 2006, NSWCCD and SAIC installed two HGMS arrays in the SEAFAC Static Site. In June 2008, NSWCCD and SAIC removed the RESAS arrays and successfully installed two HGMS arrays in the SEAFAC Underway Site. The following details the features of the arrays as well as their mobilization and installation at SEAFAC.

II. SEAFAC Site Description

SEAFAC is comprised of three primary sites: the Shore Facility, the Static Site, and the Underway Site. The purpose of these sites is to conduct robust, accurate, and detailed acoustic trials of both the newly commissioned advanced submarine classes as well as the existing in-service classes. Figure 1 for an aerial view of the SEAFAC Shore Facility.

Figure 1 – Southeast Alaska Acoustic Measurement Facility, Back Island, Alaska

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The Shore Facility serves as an analysis laboratory, maintenance facility, as well as berthing and galley services for the trials crew. A small team of SAIC support contractors and a government representative are located at this facility for full time operations and maintenance purposes. Government specialists are brought up when needed, staying at the Shore Facility during the 24-hour operations of a trial.

The Static Site is a permanently moored site consisting of two barges, corner buoys, and various other components. This facility was upgraded to HGMS capability in 2006 and will not be addressed in detail here.

The Underway Site in-water system consists of two, fixed, single-point moored arrays with custom and commercial-off-the-shelf (COTS) cables connecting it to the Shore Facility. The arrays are powered from the shore, using a commercial power supply, and are outfitted with a seawater ground return. Refer to Figure 2 for a schematic of the installed configuration of these arrays.

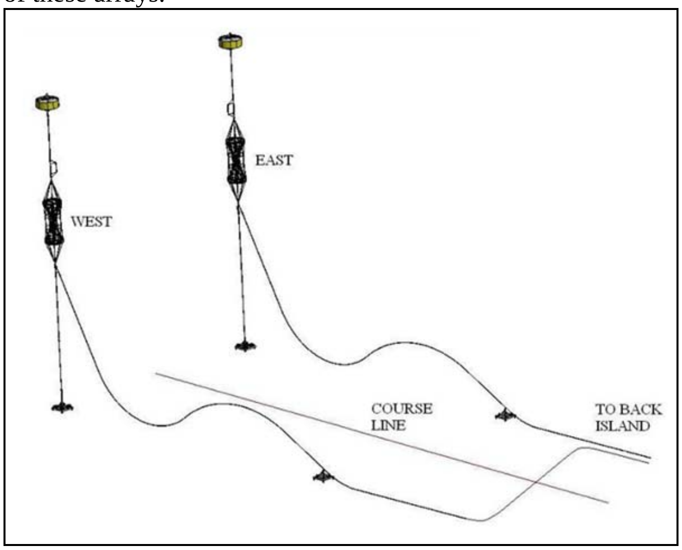

Figure 2 – SEAFAC HGMS Arrays

III. Description of Wet-End hardware

Each of the two installed HGMS arrays, identified as East and West, are comprised of a 1,120-foot long string of components, anchored in approximately 1,250 feet of water, and only 280 yards apart from each other. The six major components, listed from top to bottom, are:

1) Submerged buoy: molded foam buoy approximately 10.5 feet tall and 7 feet in diameter,
2) Upper riser: consisting of a synthetic rope on which are mounted two wideband omni-directional (WBO) hydrophones and outfitted with incrementally spaced, dual lifting-eyes for handling;
3) High Frequency Array (HFA),
4) HGMS Array (also known as the Twisted Bi-Cone Array or TBCA): approximately 28 feet tall with a 10-foot diameter,
5) Lower riser: consisting of a synthetic line on which are mounted six WBO hydrophones and outfitted with incrementally spaced, dual, lifting-eyes for handling, and finally
6) Array anchor: consisting of weights on a steel frame.

The West HGMS array also includes two additional sensors, one Vector Sensor Array (VSA) on the upper riser and one on the lower riser. Except for the VSAs, the East and West Arrays are identical.

Two submarine cable assemblies connect each array to shore. These too are identical except for position and cable length. Each cable assembly has three components.

1) *Umbilical cable*: an armored, dynamic, umbilical cable manufactured by South Bay Cable; consisting of redundant electrical conductors and single-mode optical fibers.
2) *Shore cable anchor*: a steel weldment with anti-sliding features that supports the connection between the umbilical and shore cables and provides the location for the seawater return ground.
3) *Shore cable*: an approximately 30,000-foot long Tyco® (Tyco International Services AG) SL-12 SA telecom cable connecting the umbilical cable to the SEAFAC Shore Facility.

The dynamic umbilical cable makes the connection between the HGMS array at 400 feet of seawater and the SL-12 SA shore cable at the sea floor. To facilitate this transition, each umbilical cable has two mechanical PMI Industries, Inc. DYNA-GRIP® terminations, attaching to the upper and lower connection points, on each end. In addition, strategically placed floats and ballast weights are located along the length of the cable, creating a sinusoidal curve referred to as the "lazy-S." The installed umbilical cable configuration is suspended in the water column and possesses enough slack to allow the HGMS array to move dynamically in the currents as well as to raise the HGMS array to the surface without displacing the shore cable anchor during periods of technical refresh.

IV. Mobilization

A. *Summary of Cable Installation Equipment*

A cable lay barge, owned by Southeast Stevedoring of Ketchikan, Alaska, was modified to accommodate a specialized 14-foot winch for cable deployment. The 14-foot winch was specifically fabricated for cable installation including being outfitted with a divider, cable reel machinery, and reel control station. In addition, the barge was outfitted with pad eyes and chutes for specialized cable-handling equipment designed and fabricated by Harbor Offshore of Ventura, California.

Once major outfitting of the cable lay barge was complete Harbor Offshore completed the modifications by adding lighting, scaffolds, depth sounder, and navigation system.

A pair of tugs, a twin-screw tug (owned by Amak Towing, Ketchikan, Alaska) and a Z-drive tractor tug (owned by Western Towboat of Seattle, Washington), were contracted to control the speed and direction of the barge during the cable lay. Upon arrival of tugboats and the barge in Ketchikan, a trial run of the cable route placement line was conducted along each of the planned cable routes to ensure readiness for installation.

B. Summary of Array Installation Equipment

For deployment of the array two barges, a 150-foot long mooring barge with a 45-foot beam (outfitted with winches and an 80-ton crane) and a 110-foot long installation barge with a 35-foot beam (both owned by Amak Towing) were mobilized. A twin-screw tug (from Amak) was utilized to set the moorings, move the barges, and provide emergency standby support.

The array itself was assembled, tested, and mobilized at the SEAFAC Shore Facility. Individual components were manufactured throughout the United States and Europe and shipped to the SEAFAC facility, where they were assembled and tested by SAIC and NSWCCD engineers and technicians. Immediately prior to installation, the applicable array was staged on the mooring. Refer to Figure 3 and Figure 4 for pictures of the array mobilization.

Figure 3 – Array Buildup Staging, SEAFAC Warehouse

V. INSTALLATION SEQUENCE

Prior to commencement of the installation activities, the RESAS arrays and their associated shore cables were removed from the site. Each legacy array was recovered using a remotely operated vehicle (ROV) from Northwest Underwater Construction. The shore cables were then connected to new tracking nodes and relocated away from the course track of the new shore cable.

With the legacy arrays removed, the site was cleared for the installation of the mooring barge into a three-point moor. The use of a tri-moor allowed the mooring barge to move during the installation process and thus was carefully selected to ensure that the arrays could be located in the precise, planned location. This also ensured that the “lazy-S” umbilical could be deployed and secured overnight to the mooring barge between installation phases. Refer to Figure 5 for a picture of a mooring buoy for the tri-moor being towed into position.

Figure 4 – Array Staging on Deployment Barge

Figure 5 – Mooring Barge Mooring Buoy Installation

The installation was completed in four sequential phases. First, the West cable was deployed and connected to the shore. The following day, the West array was connected to the shore cable and installed. Next, the East cable was deployed, and the East array was installed the following day.

A. Cable Installation

At the conclusion of the initial preparation activities, the cable installation began. The cable was installed from the planned array location in Behm Canal to shore. This was completed in two separate phases: first, the West array cable and then the East array cable. Each cable was installed using the cable lay barge and tugs (refer to Figure 6).

Figure 6 – Tugs and Cable Lay Barge during SEAFAC Cable Installation

To start the cable installation, the array end of the umbilical cable was passed from the cable lay barge to the mooring barge and secured to the side. Then the cable lay barge began a slow payout of the umbilical cable, with a slight backwards trend down-course from the deployment barge. At preset intervals, floats and weights were assembled onto the umbilical to create the "lazy-S" configuration. Each weight or float was assembled by hand and sent over the deployment chute. Refer to Figure 7 and Figure 8for pictures of these assemblies.

Figure 7 – Umbilical Cable Floats

With the umbilical cable fully deployed, the shore cable anchor was lifted overboard by the barge crane. The SL12-SA located on the cable lay barge winch then took up the load from the crane onto the SL12-SA. While carefully monitoring tension, the SL12-SA was lowered until the shore cable anchor was accurately placed on the seafloor, some 1,250 feet down. Then the SL12-SA cable lay began.

Following the umbilical cable installation, the SL12-SA cable was laid down. Using real-time navigation, the navigator mapped the installation path of the cable lay barge with respect to the planned installation path, guiding the two-tug boats on slight course adjustments, as needed, as well as monitoring the payout speed of the barge winch. The installation speed was approximately 1 knot.

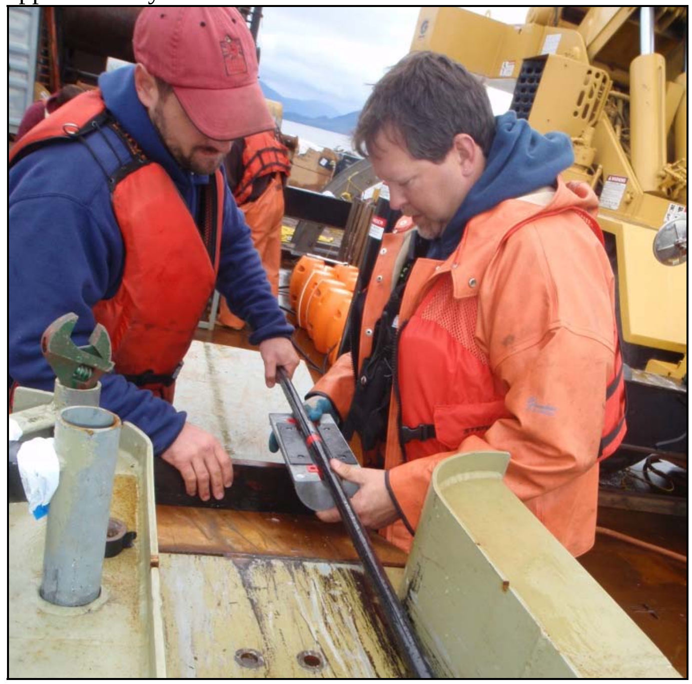

Figure 8 – Umbilical Ballast Weights

During site construction in the early 1990s, extra pipe conduit of varying diameters was run through the sea/shore interface, allowing for easy upgrade of the facilities capabilities. During the cable installation, a team of divers completed the installation of a messenger line for pulling the shore cable through one of these additional conduits. Upon reaching the shore landing-site, the cable installation crew lowered the shore cable down to the diver, where it was connected to the messenger line. Upon giving the go-ahead, the shore team pulled the cable ashore through the conduit and into the Shore Facility for termination. Once fully connected the cable was verified.

B. Array Installation

As with the cables, the East and West arrays were installed in sequence and were installed following the cable lay. The pertinent array, East or West, was pre-staged on the deployment barge the day prior to the array installation (during the cable lay). For staging, the HGMS array was located in a custom-built, hydraulic tilt table with the remaining array string faked out around the frame.

Once the deployment barge was located adjacent to the mooring barge in Behm Canal, the installation of the array commenced. The 80-ton Manitowoc® (Manitowoc Crane Companies, Inc.) crane, located on the mooring barge, connected to one of two synthetic lifting eyes 50 feet above the anchor attachment point and lowered until the crane hook was at deck level. With the second lifting eye within reach, the deck crew connected it to a custom bollard, located on the stern of the deployment barge, and the crane lowered the weight to the bollard. With the bollard taking the weight of the anchor, the crane was free to move forward and pick up the second 50-foot section of the array string. Repeating the same sequence as before, the crane attached to one of the two eyes and lifted the load free from the bollard. The deck crew released the second eye on the bollard and prepared to receive another eye from the lowering of the crane. This was repeated until a preset location was reached and progress was slowed for the connection of an omni-directional hydrophone. Once engineers at the Shore Facility confirmed the hydrophone signal, the array was lowered, and the process continued. Refer to Figure 9.

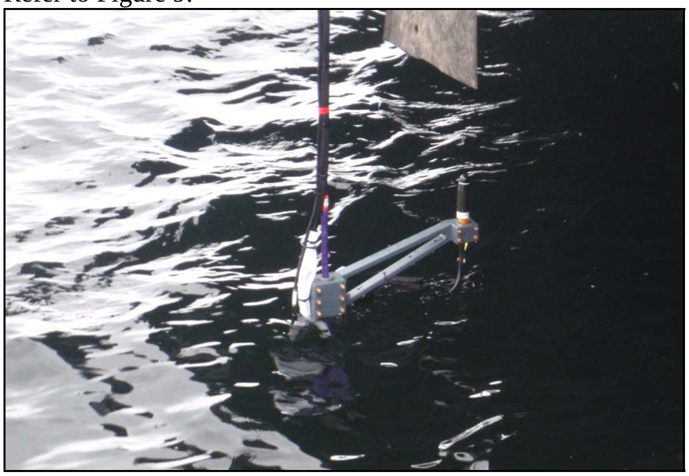

Figure 9 – Wide Band Omni Hydrophone Installation

In addition to the hydrophones, a specialized array, the VSA, was located at two depths on the West Array. The VSA is a 25-foot long array located 48 inches away from the primary strength riser. These risers were carefully lifted into the air upside down during the crane pick prior to its installation and subsequently up righted and lowered into the water. Refer to Figure 10 for the VSA being lowered into the water.

After 500 feet of lowering the lower riser, the final eye was reached and tied off. The upper clevis on the lower riser was secured immediately below the HGMS array and secured to the barge. The umbilical cable was then electrically and optically connected to the HGMS array, lower riser, HFA, VSA, and upper riser. The entire system was checked end-to-end to ensure each component functioned as intended.

With the functional testing complete, the crane was rigged for the lift of the HGMS frame. The crane connection on the upper riser was just above the HFA and was 80 feet above the lower riser connection secured to the deck (refer to Figure 11). With the lower riser and umbilical cable securely fixed on the bow of the barge, the lift began. In a carefully timed sequence, the crane lifted the HFA and upper bridle upwards while the hydraulic tilt frame raised the HGMS array vertically (refer to Figure 12). Once nearly vertical, the hydraulic table was locked into position. The crane lifted the entire load, including the carefully dressed lower bridle, to the fully vertical position, an in-air height of 80 feet. With the HGMS array free from the cradle the crane picked to entire load, approximately 21,000 pounds of static loading, off the barge (refer to Figure 13) and began lowering it into the water.

Figure 10 – Vector Sensor Array Installation

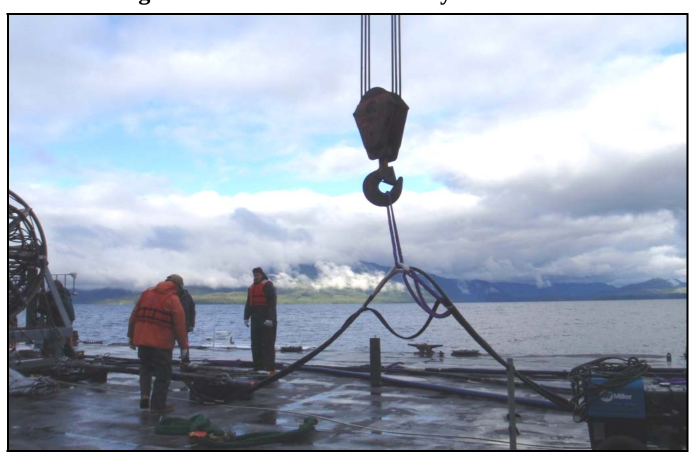

Figure 11 – Upper Riser Lift, First Step of HGMS Lift

With the HGMS array and HFA submerged, the synthetic eye was connected to the bollard and the previous sequence of 50-foot picks resumed deploying the upper riser cable.

A hydraulic release and recovery line, connected to a winch on the mooring barge, were pre-staged on the subsurface buoy. With the upper riser tied off to the bollard, the crane was connected to the lifting line above the hydraulic release and lifted the buoy above the tied-off array. After attaching the final components together, the crane picked up the load of the array for the final time and lowered it until the recovery line and winch took the load.

Figure 12 – HGMS Lift, Second Step

Figure 13 – HGMS Full Lift, 80' Pick, Final Step

Using the tri-moor winches and SEAFAC tracking system, the mooring barge was carefully positioned into the desired location. After allowing the barges to settle into the exact deployment location, the recovery line was lowered and the array set onto the seafloor. Once it was verified that the load was off the recovery winch, the hydraulic shackle was released and recovered to the surface. Refer to Figure 14.

Figure 14 – Buoy Installation with Hydraulic Release

C. *Installed Configuration*

By using the existing SEAFAC tracking system, adjustable tri-moor system of the barge, and patience, each array was positioned to within feet of the planned installation location. The arrays, for submarine safety and highly precise acoustic measurements, were to be positioned within 280 yards of each other and precisely across the course line.

VI. CONCLUSION

The upgrade of the SEAFAC Underway Site delivered the measurement capabilities required for assessing the stealth of advanced submarine classes while maintaining its ability to assess the existing submarine fleet. NSWCCD completed system validation in less than two months after HGMS installation and successfully conducted a full-scale acoustic trial on the USS JIMMY CARTER (SSN-23). Each subsequent acoustic trial, occurring with consistent frequency, assures the submarine fleet of its tactical advantage and affirms that SEAFAC checks the health of stealth.

ACKNOWLEDGMENT

The authors of this paper[1] would like to thank the NSWCCD engineers, the SAIC engineers and SEAFAC on-site team as well as the Amak and Harbor Offshore teams for their support, long hours, and unwavering dedication to achieving a successful installation.

[1] SPRN 09-SAIC-0825-02